LBID-2410

Report of the LBNL Committee to Review the Development of a Far-IR Ring at the ALS
14 March 2002

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A group at the Advanced Light Source (ALS) is conducting developmental research on the pre-conceptual design of a super-radiant far-infrared synchrotron radiation source. This group asked the Integrated Project Management Office to conduct a review of development plans for this source.

The source is a small storage ring specifically optimized for the production of infrared synchrotron radiation especially in the far infrared. The concept is to use the existing ALS linac and booster ring to inject into a new small storage ring located on or inside the present ALS booster tunnel. This ring will utilize presently empty space for new infrared beamlines. The desire is to produce ultra short electron bunches (<100 micron) to produce very large fluxes in the 100-1000 micron wavelength range (the Terahertz [THz] frequency regime).

It is asserted that a source in the far-IR that is much brighter than what is presently available would open up new possibilities for research in this traditionally difficult photon energy range. It is also asserted that super-radiant temporally coherent synchrotron radiation could significantly enhance the available photon flux at far-infrared wavelengths. At wavelengths longer than the electron bunch length in a storage ring the individual electrons radiate in phase. This coherent radiative power would be proportional to the square of the number of electrons in contrast to the linear relationship of incoherent synchrotron light sources. Even at very low beam currents (1microampere) this flux enhancement should be quite large.

The Committee was asked to specifically examine four questions with regard to the pre-conceptual development of this source. Committee findings, comments and recommendations are loosely grouped by these questions. A general summary section concludes this report. Appendix A of this report lists the review committee members. Appendix B is a copy of the Charge to the committee and Appendix C is a copy of the Agenda.

1. Scientific Case

Is the case for possible contribution to science that will be afforded by this source being developed in a compelling manner? Is the plan for a comparison of the relative merits of this proposed ring-based source with alternative far-IR sources reasonable?

Findings

- The approach for the IR-Ring has, until recently, been focused on principally providing additional capacity with a high current incoherent ring source with a low-current, low-energy, coherent operational configuration. The coherent mode, until recently, was not viewed as the driving characteristic or motivation for the development.

Comments

- It is not clear there is any need for the conventional mode operation of the ring at this time. A 1-ampere, 700 MeV ring may not make a compelling enough case to successfully compete for distinct funding. Consequently, emphasis should be focused on the source operating in coherent mode. Consistent with operating in the coherent mode, the widest possible spectral region in the IR should be pursued, since it might result in a broader scientific program.

- The comparison between the THz source and the IR-Ring may not be on an equivalent basis. The THz system employs coherent detection and time gating and so has the advantage of a large synchronous detection noise reduction. This means that the noise rejection and signal-to-noise ratio is larger for a smaller flux. The IR-Ring may not have this advantage; hence, the signal-to-noise could be lower for an equal number of photons. A complete system analysis (taking fully into account reduction techniques presented by M. Martin) is essential for a valid comparison of the IR-Ring and the THz source.

- Given that the coherent mode of operation is likely the most defining characteristic of the source, a very exciting aspect in early research and development of the source would be to use a beam splitter to interfere the beam with itself. Such interference would allow the system to benefit from synchronous detection approaches that would significantly enhance the signal-to-noise ratio. One possible application with such an approach would be the study of non-linear conductivity in metals.

- The group is to be commended for the quality of the development. The group does not view this as an accelerator development with a scientific case for justification, but rather scientific needs driving accelerator development. It is very pleasing to see the supporting partnership accelerator physics plays with the scientific development as the project progresses.

Recommendations

- The IR-ring should be keyed to a substantial enough specific class of users rather than attempting to be a global solution without identified strong proponents.

- The group should reconsider and start with a reverse strategy. Start with the goal of creating a suitable coherent far-infrared source driven by the most compelling scientific requirements. The group should subsequently proceed to the specific development requirements and implementation.

2.Technical

Are there technical challenges that have not been identified or given proper attention for development?

Findings

- The team has only initially started to assess the full implications of source with emphasis on coherent mode operation.

- The present system is envisaged as being capable of top-off mode injection, though assessments of the feasibility with respect to beam stability are acknowledged as not yet having been undertaken.

- The alignment tolerances are 3-5 times larger than those of the ALS. Presently it is assumed that the shielding roof over the IR-Ring would need to be removed for alignment. The deflections of the floor (booster tunnel roof) with and without the shielding have not been assessed.

Comments

- A very different configuration could likely occur if an original assumed requirement and an initial goal were lifted: the requirement that placement is on top of the booster tunnel and that increasing total capacity is a primary goal. It is likely that placement other than on top of the booster tunnel could be problematic for an ALS/LBNL related instrument. An awareness of the implications of such a requirement will strengthen the overall case of the proposed project.

- Using the NSLS-VUV storage ring, as a starting configuration point, may not be the best approach either from a source, scientific, or development perspective. Starting from initial scientific goals and developing a coherent source based on requirements derived from those goals could result in a different configuration.

- The installation of the IR-Ring in the booster is not a viable site option. There is a possibility that the booster tunnel could be declared a confined space if the IR-Ring were installed in the tunnel. There is also a large probability of major impacts and disruptions on ALS operation. Both of these issues drive this comment.

- The shielding differences between the coherent and high-current modes should receive further study. The large difference in current between the two modes might be exploited to lower requirements of the coherent mode.

- The present coherent operation is based on the superconducting RF-cavities with an operating frequency of 1.5 GHz. It may be advisable to look at starting with a level of coherent operation employing warm cavities that can be later upgraded to superconducting RF.

- A competing coherent source based on some other technology may be able to cover the 10μm - 100μm spectral regime that is lacking in the proposed configuration. This

may be viewed by some as narrowing the scientific applicability of the ALS IR-Ring. In a effort to counter such an issue, the group should avoid the temptation to use the "unexplained" observed levels of coherence in the 10μm - 100μm as a partial justification of the project or in possibly providing a meaningful source of radiation in this region.

- The group is to be commended for the accelerator physics being conducted at the ALS in connection with this source development. Such engaging physics helps retain the most talented people and ensures the ALS will remain a state-of-the-art facility.

Recommendations

- An experimental program for increased characterization and demonstration of possible scientific applications is absolutely necessary for the coherent mode.

- The impact of stray light vacuum chamber reflections requires additional study.

- As quickly as possible, the group must document that the operating characteristics for the coherent mode lie squarely within the stable regime. This instability and possible increased noise resulting from the radiation impedance needs further analysis and clarification. As presented, the possibility of unstable operation will cause a degree of uncertainty in prospective users that could compromise the support for the source.

- There should be a concerted effort to synchronize IR source measurements with an external laser or otherwise seek to demonstrate the ability to exploit noise reduction afforded by synchronous detection (in a fashion analogous to FROG detection for visible lasers).

- The energy losses from the coherent and incoherent processes need to be clarified. It is possible that that loss from the coherent processes could be a substantial fraction of the total energy lost, and beam dynamics could be changed as a result. Additional lifetime calculations should be enhanced to give greater confidence in the operating characteristics of the system.

3. Schedule Plan and Estimate

Is the proposed development plan realistic, appropriate, feasible and organized in a manner that optimizes the probability of success? Are there areas that require additional attention or consideration?

Findings

- The development schedule presented included the following milestones:
    - A white paper to be delivered in July 2002 for the Scientific Advisory Committee.
    - A major workshop and vetting of the source at the ALS Users Meeting in October 2002.
    - A submission to DOE for CD-0 in March 2003.

- A preliminary cost estimate was presented with a total of approximately $20M. Some development costs, such as instrumentation and controls were missing from this initial preliminary estimate. In preparation to requesting Mission Need (CD-0) a more complete cost estimate will be required and is planned. The present cost estimate is only for the conventional mode operation and does not include any impacts of implementing the coherent mode.

- Analysis presented indicates that there should be adequate existing ALS utility and cooling capacity to accommodate the IR-Ring within the complex.

Comments

- The high-current incoherent mode is presently driving the estimated costs. Concentrating on coherent mode operation may actually reduce some budget pressures.

Recommendations

- The estimates should carefully document assumptions and move toward estimate ranges based on pessimistic and optimistic risk assumptions. The credibility in the cost ranges will be enhanced if ALS actual costs are directly compared with estimates and differences explained.

A. The group will need to revise and adjust its proposed schedule and milestones in view of the new emphasis on the coherent mode of operation. Adequate time must be provided to examine the options and configurations necessary for an optimized coherent source.

4. Resources, Priorities, and Emphasis

Are the correct resources, priorities and emphasis being applied to the development?

Findings

- The present effort on the development team is approximately 5 full time equivalents spread between scientific case development, accelerator physics development, experimental studies, and engineering analysis and pre-concept design.

Comments

- The scientific case ought to be focused to develop a compelling program. There must be an owner identified within the funding agency if a rapid development is desired. Developing this compelling scientific case and its supporters funded by the agency owner must be a top priority.

- It is not clear to the Committee that the configuration would be the ring presented if it were designed principally as a coherent source at the beginning of the development. Another possible development course would be to concentrate on a separate coherent

mode source and add capacity for non-coherent sources by adding additional IR beamlines to the ALS.

- There is a need to compare the ring source more closely to a linac-based source. It is important to understand if anyone has demonstrated an amplitude-stabilized accelerator system. It is important to demonstrate that a linac source, such as the JLab project mentioned during the review, is not a more flexible strategy. The Committee cautions, however, that noise levels are only doubled in theory between the coherent and incoherent sources. This exercise is aimed at the principal issue of stability of the source. The group should develop the most favorable configuration while gaining an appreciation and understanding of alternative approaches. It is necessary to understand competing sources better than the advocates of those sources to ensure success.

Recommendations

- An operational source based on the coherent mode should be the highest priority and is likely the only compelling approach to the development of the source. Consequently, additional engineering should be held on abeyance as the coherent case is fully developed as its pre-conceptual requirements and goals are defined.

General

Findings

- The group is to be commended for its excellent work in investigating coherence effects. It is a prime example of the quality and value of Laboratory Directed Research and Development (LDRD) funding. The group should place a high priority on publication of this work.

Comments

- A more thorough understanding of the DOE funding cycles and project development will likely enhance the probability of a timely project start and decrease wasted effort.

- While seeking DOE support, it may be possible to develop and market the IR-ring to non-DOE funding sources. The group should identify and work with partners or consultants who understand and have had success with the project development process of the non-DOE funding source.

- For the foreseeable future, from a DOE perspective, an attempt to keep the total project cost (TPC) below $20M is advantageous, because higher approval levels are required for projects above $20M. One possible way of achieving this would be to have the superconducting RF as a future upgrade. This, of course, should only be discussed and suggested in conjunction with and the agreement of ALS management and the DOE program office championing the project. There should be a study to determine if a reasonable coherent mode can be achieved initially without a superconducting RF system.

Recommendations

- In preparation for DOE Mission Need Justification (CD-0), it is more important to concentrate on understanding the uncertainties and underlying assumptions of any initial estimates. The DOE desires to see an initial estimation range. The estimates should be developed to ensure that any range has a large probability of capturing the eventual cost of the project with an understanding of the risks and uncertainties in the range.

- The group should place a high priority on publishing its experiments and studies of the coherent mode operation. Such publication will clearly establish the ALS group as a leader in this area and help to fully realize the investment of the LDRD in this area.

Appendix A

List of Committee Members, their affiliation and e-mail address:

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Appendix B

Charge for LBNL Review Development of a Far-IR Ring at the ALS
14 March 2002

A group affiliated with the Advanced Light Source (ALS) is conducting developmental research on the pre-conceptual design of a super-radiant far-infrared synchrotron radiation source. They have asked the Integrated Project Management Office to conduct a review of development plans for this source.

The source is a small storage ring specifically optimized for the production of infrared synchrotron radiation especially in the far infrared.far infrared. The concept is to use the existing ALS linac and booster ring to inject into a new small storage ring located on or inside the present ALS booster tunnel. This ring will utilize presently empty space for new infrared beamlines. The desire it to produce ultra short electron bunches (<100 micron) to produce very large fluxes in the 100-1000 micron wavelength range (the Terahertz [THz] frequency regime).

It is asserted that a source in the far-IR that is much brighter than what is presently available would open up new possibilities for research in this traditionally difficult photon energy range. It is also asserted that super-radiant temporally coherent synchrotron radiation could significantly enhance the available photon flux at far-infrared wavelengths. At wavelengths longer than the electron bunch length in a storage ring the individual electrons radiate in phase. This coherent radiative power would be proportional to the square of the number of electrons in contrast to the linear relationship of incoherent synchrotron light sources. Even at very low beam currents (1 microampere) this flux enhancement should be quite large.

The Committee is asked to specifically examine the following questions with regard to the pre-conceptual development of this source.

1. Is the case for possible contribution to science that will be afforded by this source being developed in a compelling manner? Is the plan for a comparison of the relative merits of this proposed ring-based source with alternative far-IR sources reasonable?

2. Are there technical challenges that have not been identified or given proper attention for development?

3. Is the proposed development plan realistic, appropriate, feasible and organized in a manner that optimizes the probability of success? Are there areas that require additional attention or consideration?

4. Are the correct resources, priorities and emphasis being applied to the development?

Appendix C

IR RING First Internal Review - March 14, 2002

LBNL 6-2202 Conference Room

8:00 am	*Breakfast*	
8:30 am	**Executive Section**	
9:00 am	**Welcome and Introduction**	D. Robin
9:10 am	**Applications for IR Synchrotron Radiation**	M. Martin
9:40 am	**IR Ring Overview**	J. Byrd
10:10 am	**Scientific Motivation: Strategy and Plan**	M.Martin
10:40 am	*Coffee Break*	
10:55 am	**Coherent Mode Studies: Strategy and Plan**	J.Byrd
11:25 am	**RF Frequency Decision: Strategy and Plan**	S.Kwiatkowski
11:50 am	**Photon Beam Stability: Strategy and Plan**	W.McKinney
12:15 am	*Lunch and* **Executive Section**	
1:15 pm	**Electron Beam Stability: Strategy and Plan**	W. Barry
1:40 pm	**Acc. Physics High Priority Issues: Strategy and Plan**	J.Byrd
2:00 pm	**Site Location: A Plan for the Decision**	D. Munson, W. Byrne
2:25 pm	**Engineering High Priority Issues: Strategy and Plan**	W. Thur
2:50 pm	**Costs, Schedule and Important Dates**	F.Sannibale
3:15 pm	*Break*	
3:30 pm	**Executive Section**	
4:30 pm	**Close-out Section**	The Committe